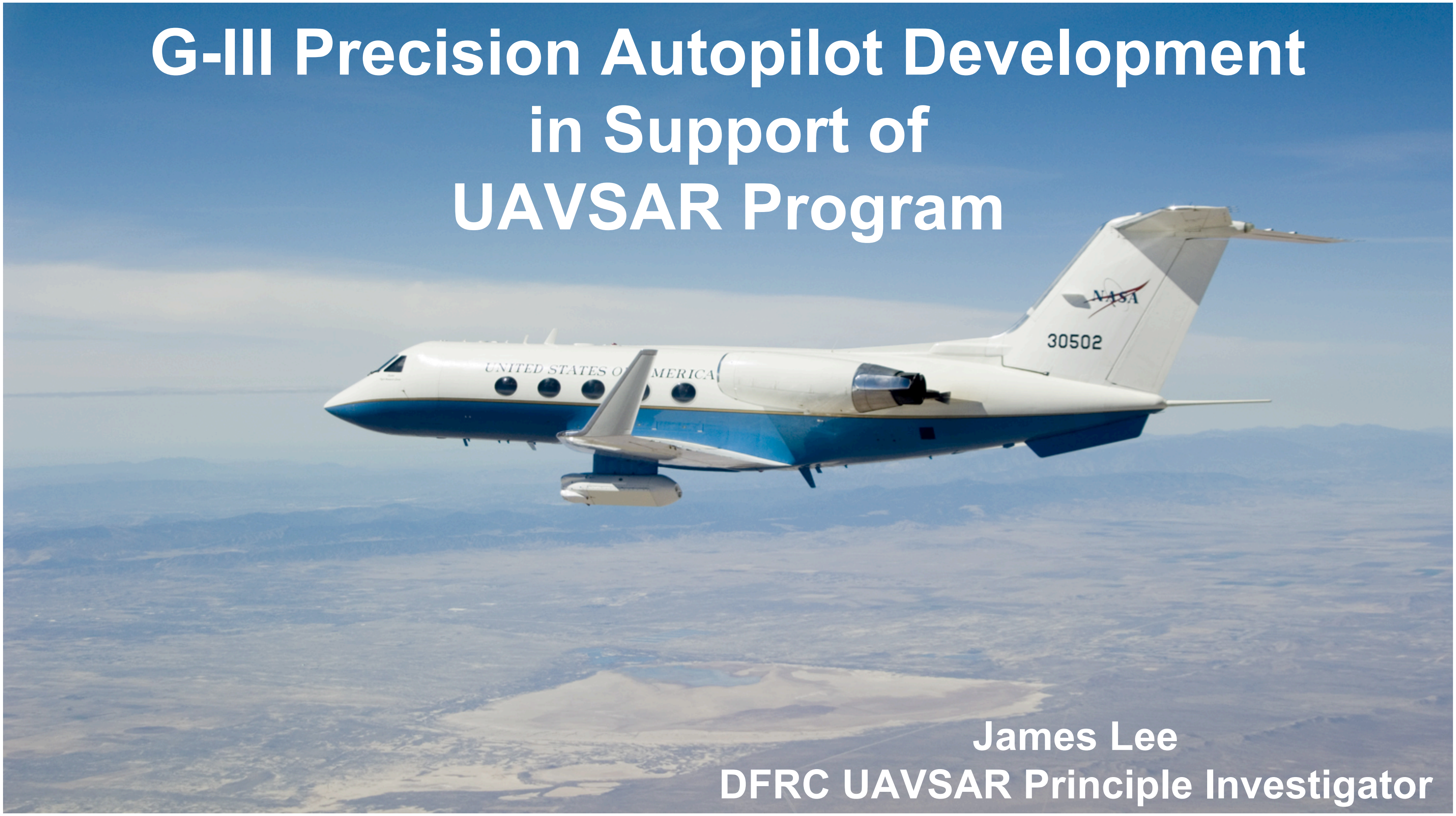
G-III Precision Autopilot Development in Support of UAVSAR Program



James Lee
DFRC UAVSAR Principle Investigator

NASA Dryden Flight Research Center

UAVSAR

- **The primary objective of the UAVSAR Project is to:**
  - Develop a miniaturized polarimetric L-band synthetic aperture radar (SAR) for use on an unmanned aerial vehicle (UAV) or minimally piloted vehicle

- **Roles & Responsibilities**
  - *JPL*
    - Lead center that will design, fabricate, install and operate the radar instrument, develop processing algorithms and conduct data analysis
  - *Dryden Flight Research Center*
    - Manage the development of pod design, fabrication and delivery to JPL
    - Deliver RPI (Repeat Pass Interferometry) interim platform and long term operational platform
      - NASA's G-III selected as the interim platform
    - Lead the platform modification effort and head up flight operations of the platform
    - Develop Platform Precision Autopilot (PPA) capability
  - *Total Aircraft Services, Inc. (TAS)*
    - Under contract to perform G-III modifications and pod fabrication

- **First Flight of SAR on G-III expected Fall 2007**

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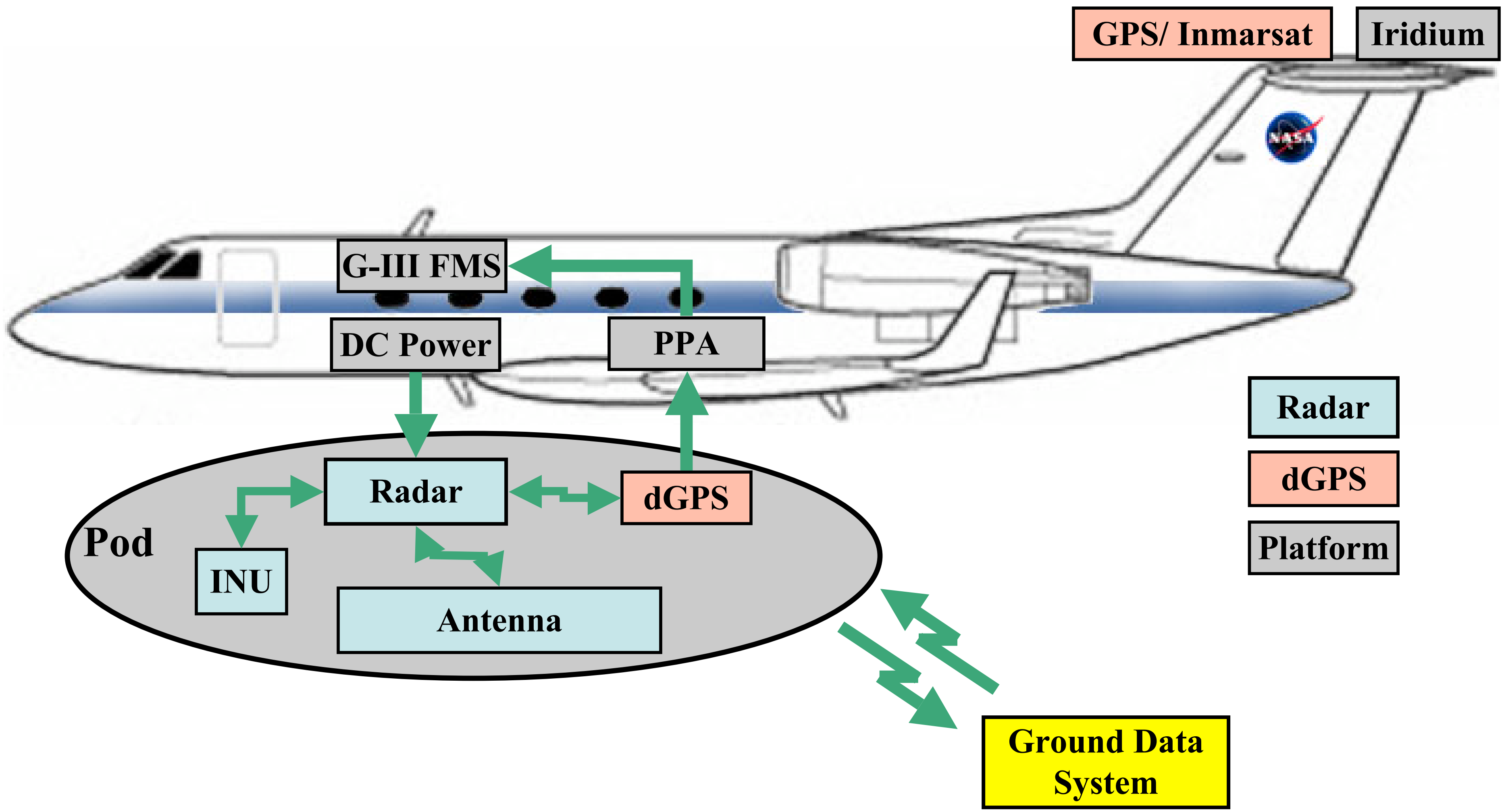
NASA Dryden’s G-III Aircraft

- **Aircraft Goal**
  - Provide a research test-bed for NASA, the Air Force, and other government agencies with a long-term capability for efficient test of subsonic flight experiments.
    - Aircraft instrumented to collect flight data

- **Aircraft Dimensions**
  - Wing: span 77 ft 10 in; area 934.6 ft^2
  - Fuselage and tail: length 83 ft 1 in; height 24 ft 4.5 in

- **Aircraft Performance**
  - Max Mach - 0.85
  - Max Operating altitude - 45Kft
  - Normal cruise – 400 to 500 kts
  - Range – ~3000 nautical miles
  - Climb – up to 4,000 fpm
  - Large Internal Volume (1500 cu. Ft.)

UAVSAR System High Level Architecture



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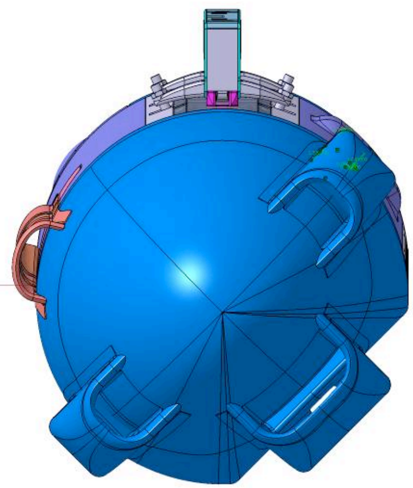
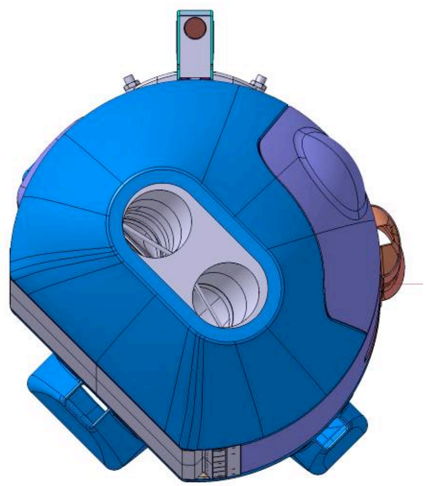
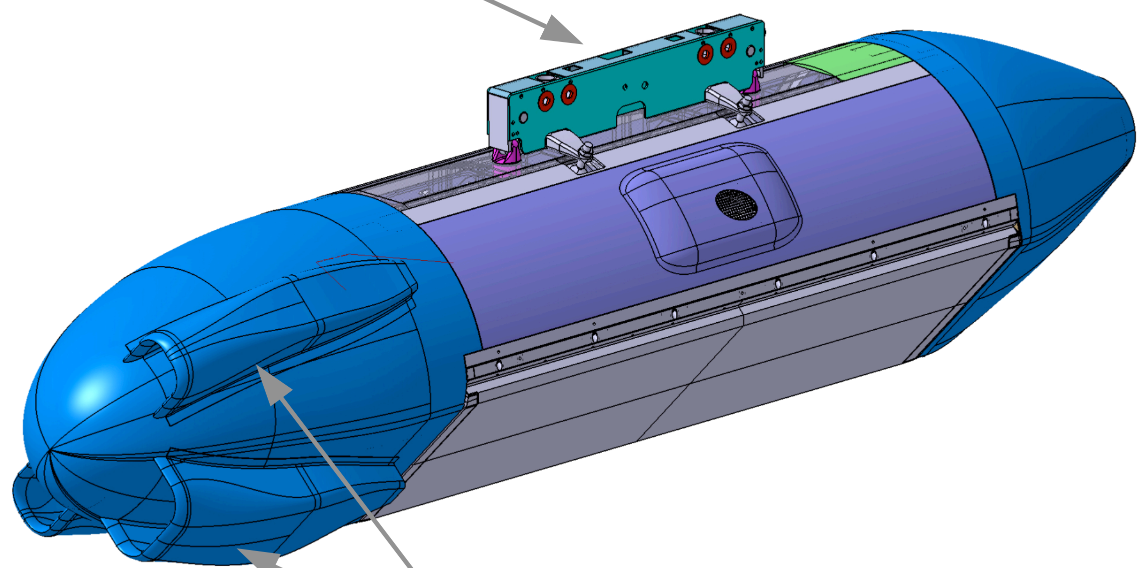
Pod Design
External Views

Front View

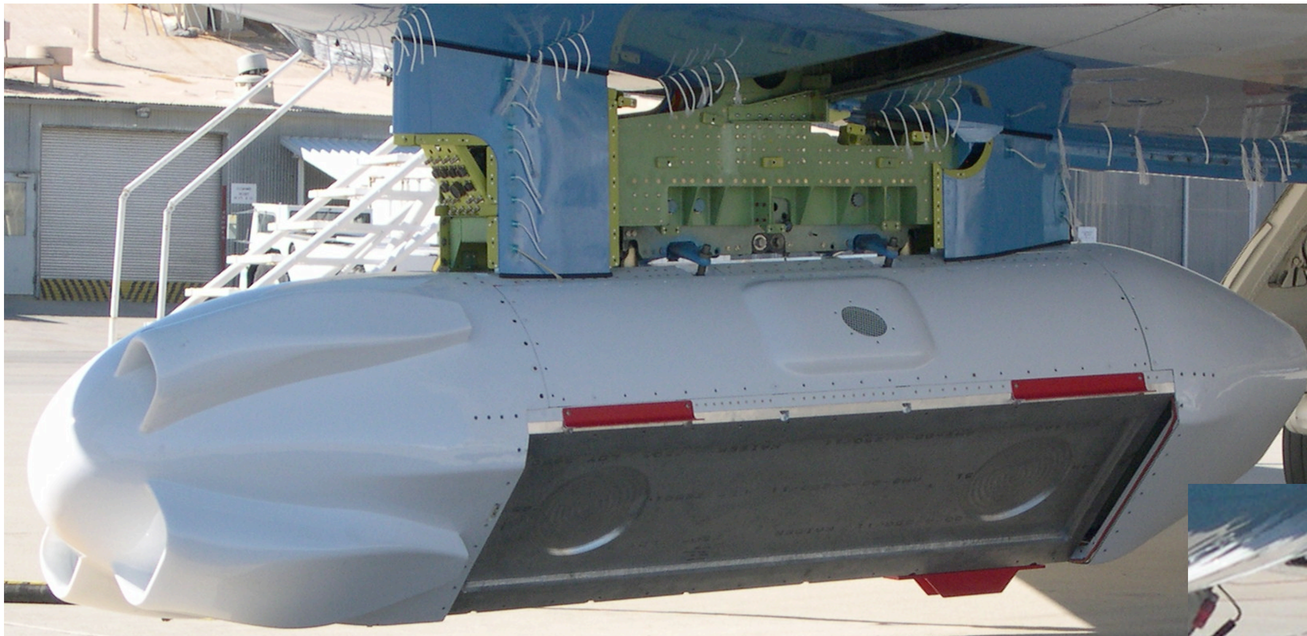


Rear View





UAVSAR Pod



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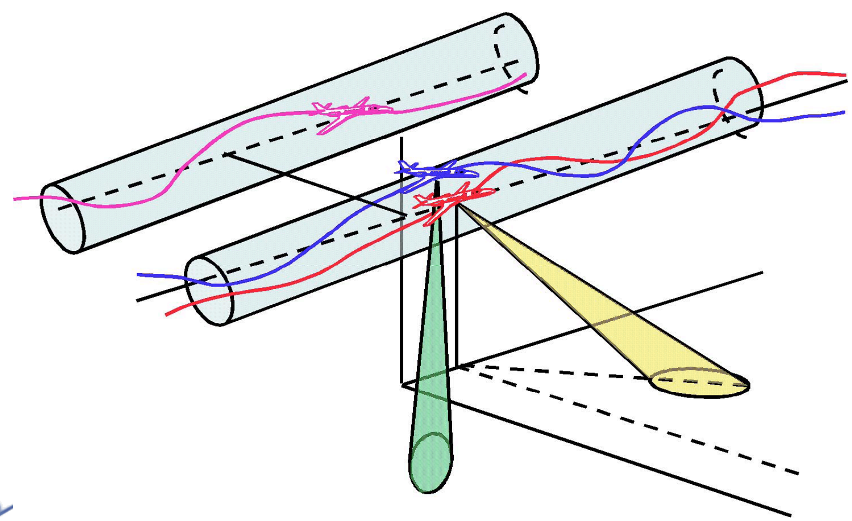
Platform Precision Autopilot (PPA) Requirements

- **Performance Requirements**
  - *The PPA shall fly the G-III within a 10 m (32.8 ft) diameter tube for at least 90% of each data take in conditions of calm to light atmospheric disturbances, as defined in MIL-STD-1797.*
  - *Minimize motion during data collection*
    - Rationale: It is critical to operate the UAVSAR System on a steady platform. This requirement will be further defined and addressed through cooperation with JPL as the PPA is developed.



PPA Development Plan

- **Overall Approach**
  - Develop the hardware and initial software to demonstrate feasibility of the approach
    - Initial software is designed to be flexible with uploadable parameters
      - Algorithms are all in Matlab/Simulink and auto-coded
      - Initial software development effort was geared toward developing tools to allow for rapid software updates.
  - Refine the navigation, guidance, and controller algorithms based on flight testing
    - Update simulation and linear models as appropriate
  - Final Product is software suitable for operation by end users
    - Gain tables part of controller (transparent to user)
    - Enhanced software restrictions for safety
    - Improved user-friendliness

PPA Development Flight Test Plan

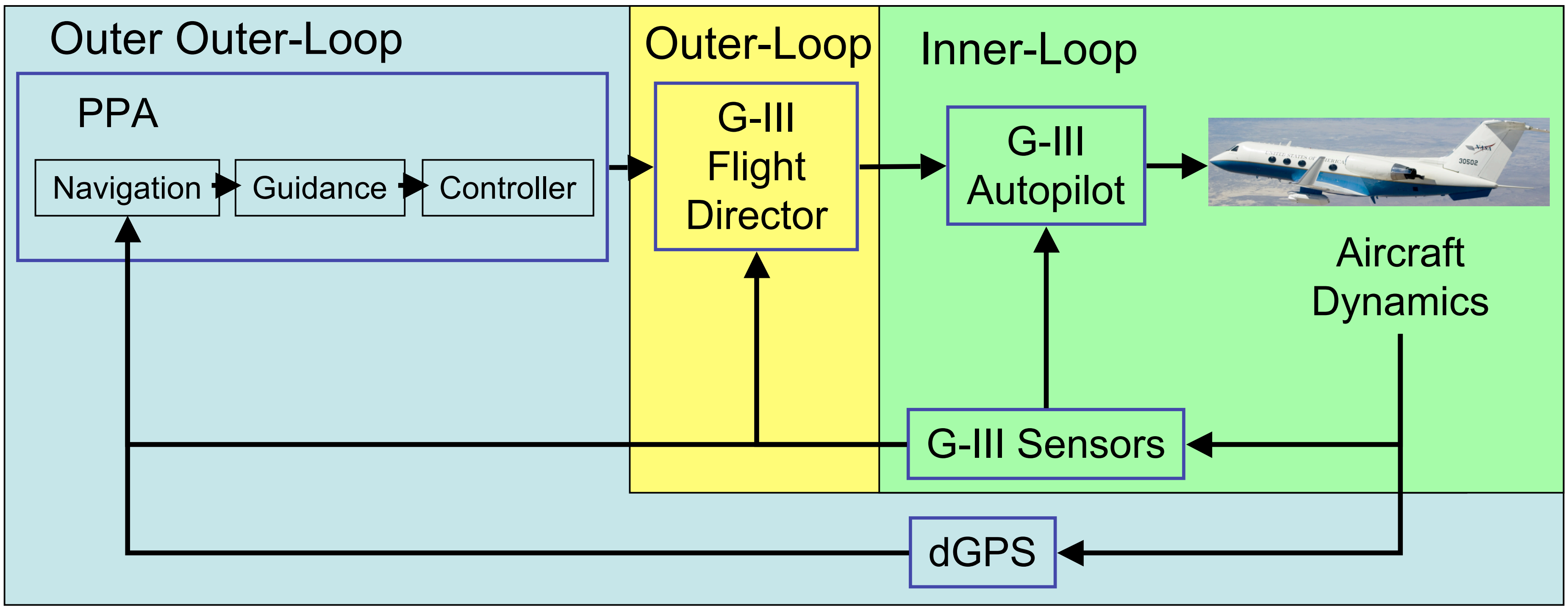
- **PPA Cycle I Controller Test Flights**
  - Description: Initial flight test of closed-loop PPA
  - Objective: Demonstrate closed-loop operation of PPA
    - Secondary Objective of demonstrating 10 m tube performance

- **Cycle II Controller Test Flights**
  - Description: Flight test of revised PPA applying lessons learned from previous flights.
  - Objective: Demonstrate 10 m (32.8 ft) tube performance. Demonstrate PPA performance with an expanded flight envelope.

- **Cycle III Controller Test Flights**
  - Description: Flight test of revised PPA
  - Objective: Demonstrate operation of PPA to customer. Further expansion of flight envelope.

PPA Control Loop Visualization

- PPA provides Outer Outer-Loop Control
- Aircraft Outer Loop controlled by G-III Flight Director
- Aircraft Inner-Loop dynamics stabilized by G-III Autopilot



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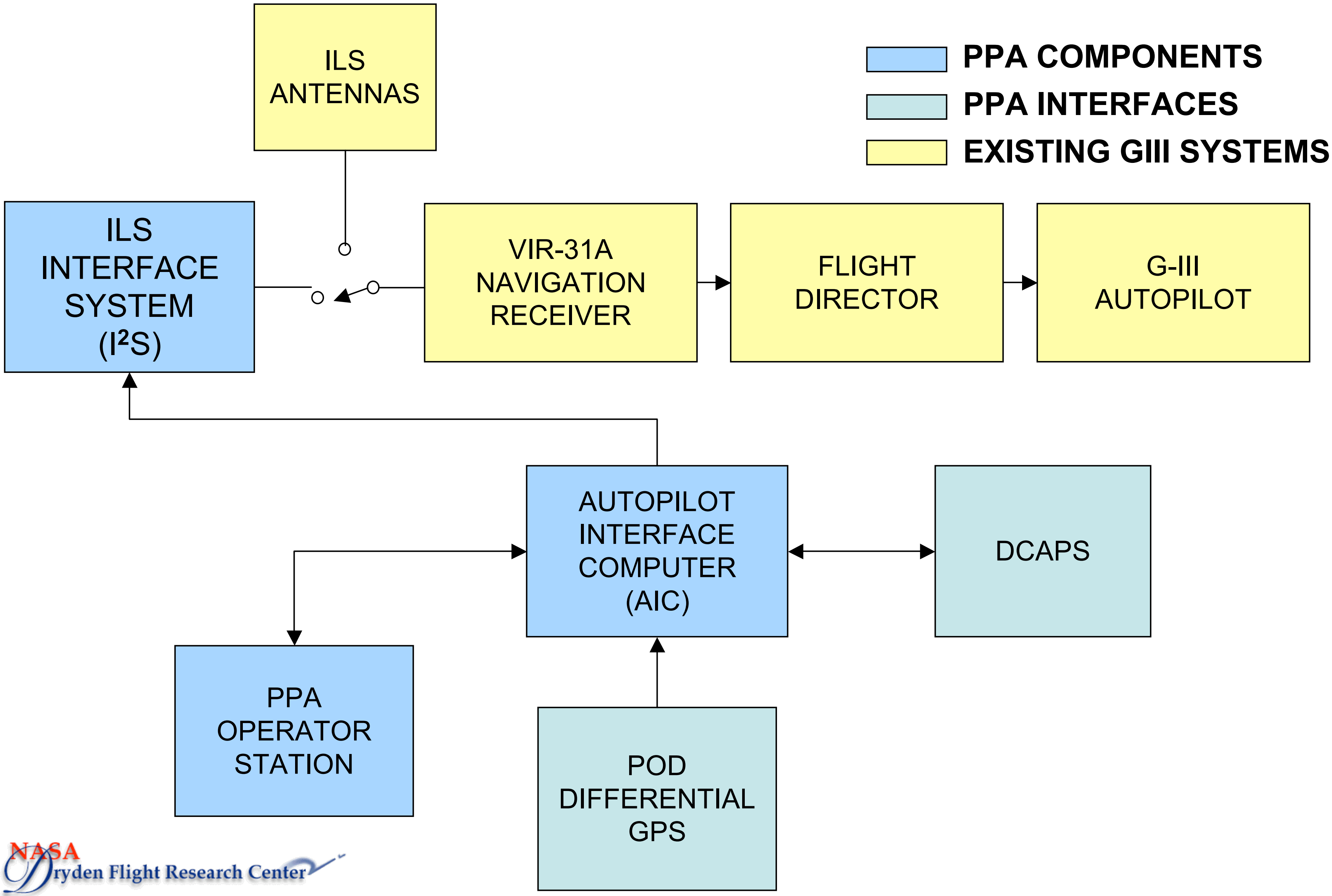
PPA Hardware Interfaces



PPA Hardware Subsystems

- **Autopilot Interface Computer (AIC)**
  - Host the PPA guidance, navigation, and control algorithms
  - Interface to external digital data sources
    - GIII navigation data via DCAPS from ARINC 429 bus
    - Differential GPS from dGPS in radar pod
  - Output commands to I^2S
  - Interface to operator station for waypoint and gain input, and AIC telemetry

- **ILS Interface System (I^2S)**
  - Modulate the ILS control signal based on input from AIC
  - Provide the ILS glideslope (GS) and localizer (LOC) RF signals

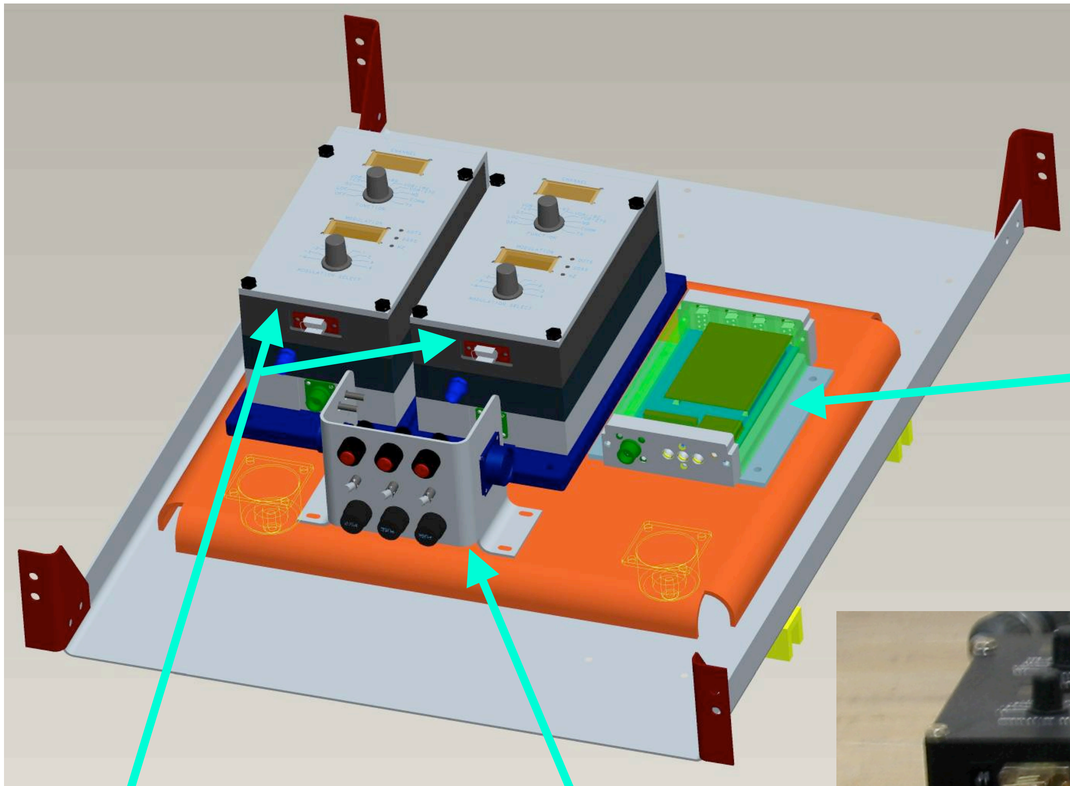
PPA Hardware Subsystems (cont.)

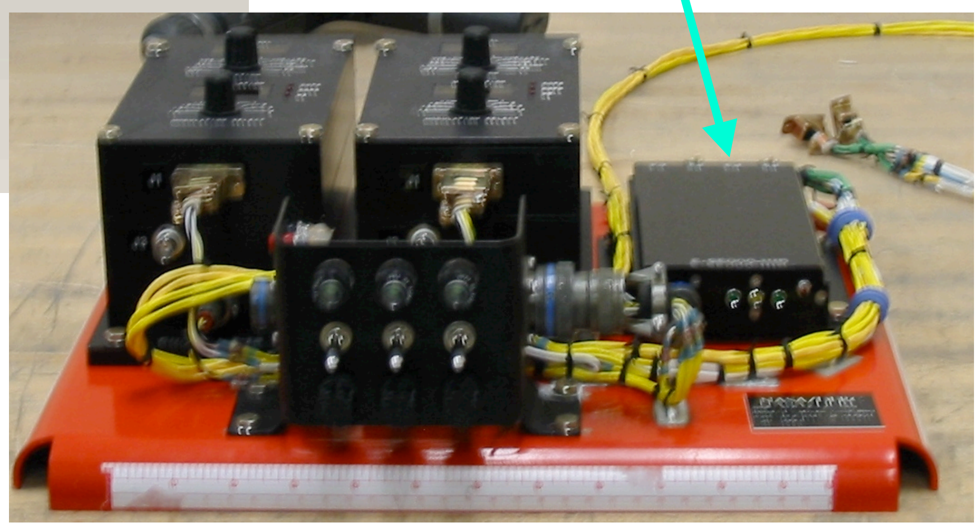
- **Operator’s Station**
  - Display status and performance information in flight
  - Record the telemetry data (entire PPA input/output plane)
  - Upload gains, waypoints, altitude
  - Command navigation initialization and error status reset
  - Command PPA engage and disengage

- **RF Switches**
  - Select between ILS antennas and I^2S signal

- **Power Distribution Panel (PDP)**
  - Fuse protection for PPA components
  - Power control for PPA components

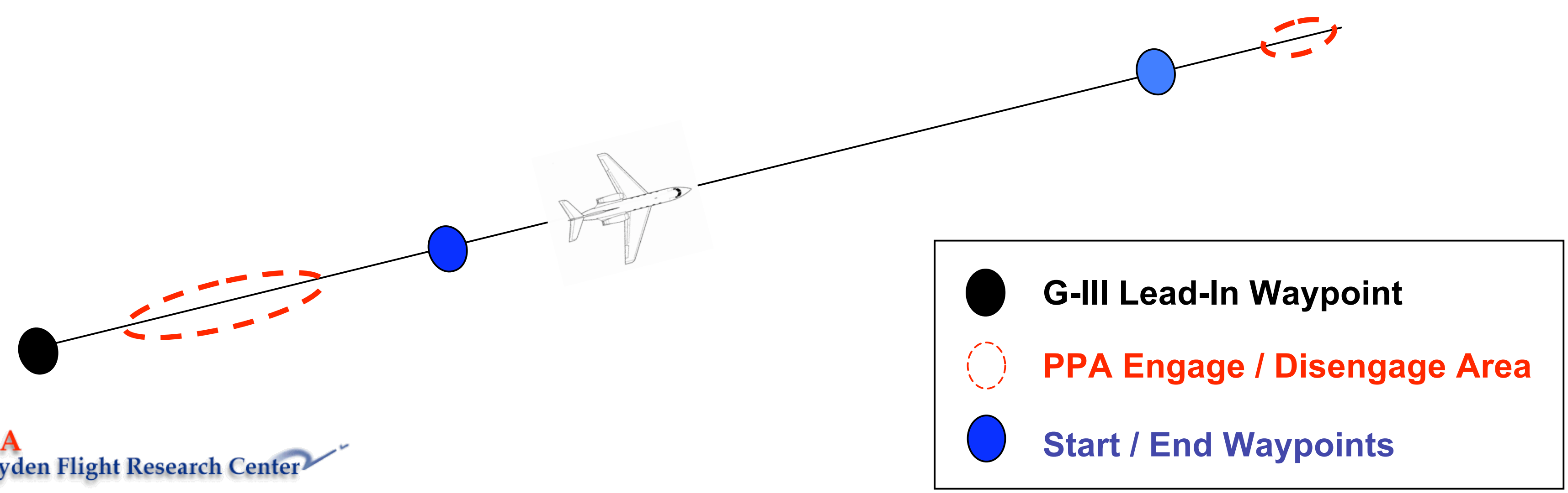
PPA Pallet on Experiment Rack





Closed Loop Courses

- Courses
  - Distance between start and end waypoints 80 – 150 nm (~ 10 – 20 minutes)
  - Headings
    - •North – south
    - •East – west
    - •Diagonal
  - Pilot flies aircraft near the segment between the lead-in and start waypoints
    - •Navigation guidance from PPA operator
- Operator will determine when to engage PPA during flights



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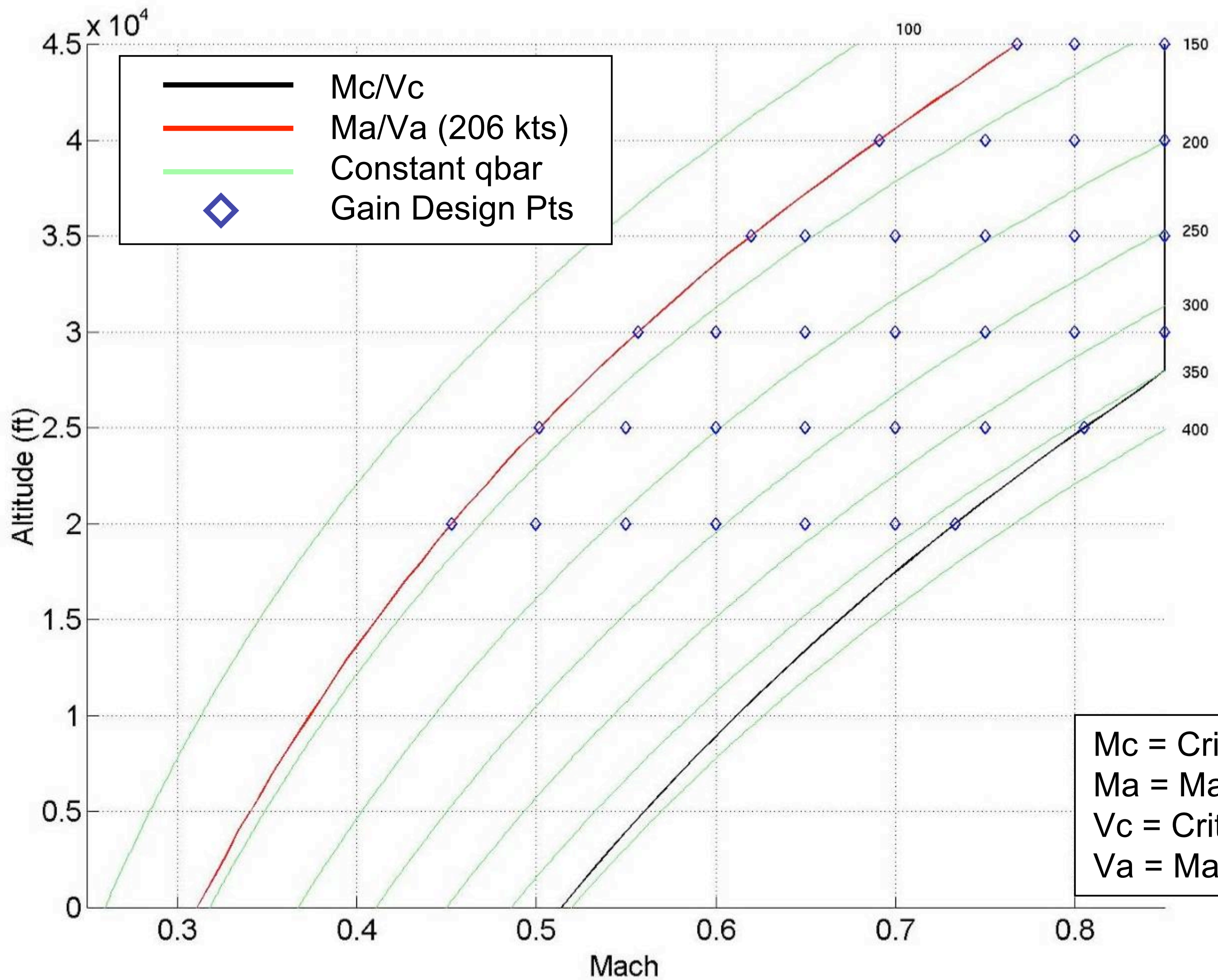
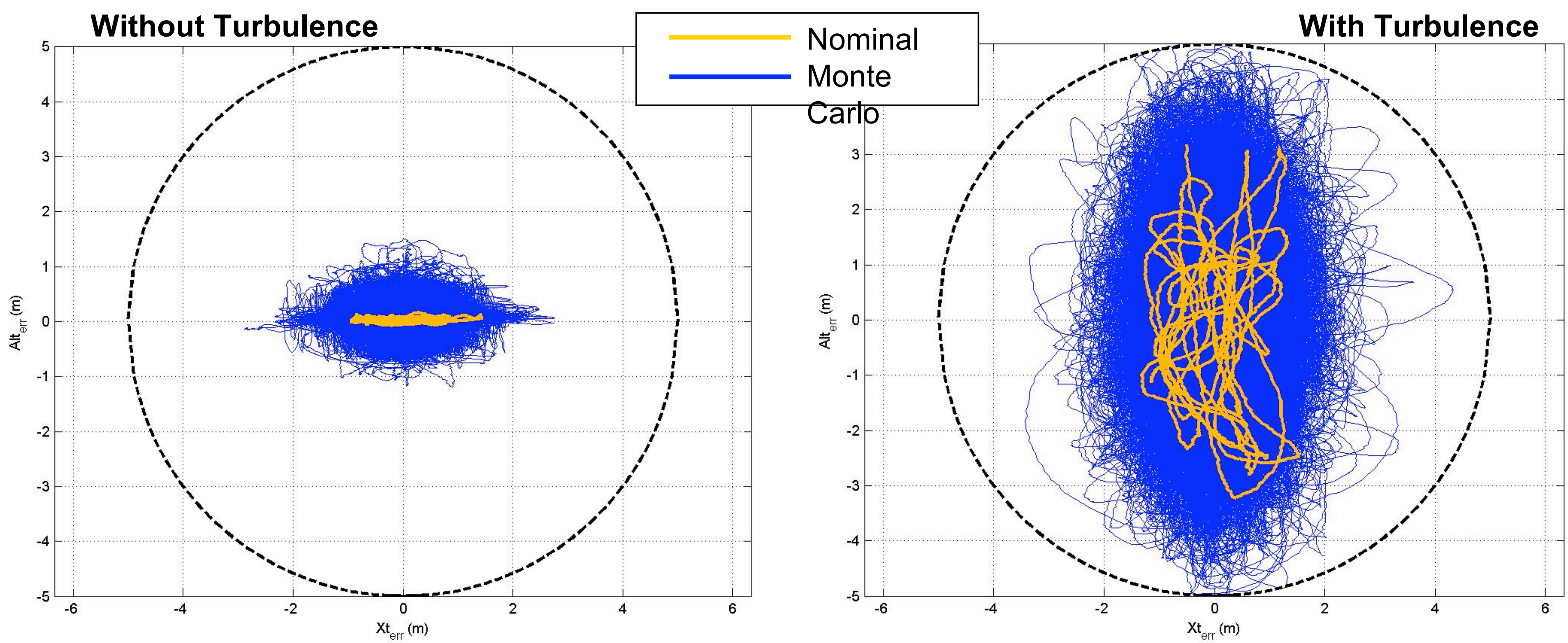
PPA Planned Flight Envelope



Mc = Critical Mach
Ma = Maneuvering Mach
Vc = Critical Speed
Va = Maneuvering Speed

Monte Carlo Simulation Results
10 m. Tube Performance

- **Monte Carlo analysis conducted with GIII simulation**
  - Consists of randomly perturbing simulation parameters within specified bounds.
    - Approximately 45 simulation parameters perturbed including: aerodynamics, mass properties, system timing, winds.
    - 500 simulation runs were conducted at each specific flight condition.
      - With and without light turbulence



Conclusions

- **Three Cycle 1 precision autopilot flights have been completed as of April 20, 2007**
  - First flight was open-loop controller
  - Second and third flights were closed loop
    - Third flight demonstrated increasing duration within ten meter tube

- **Additional Work:**
  - Expand flight envelope
  - Further refinement of Navigation, Guidance, and Control algorithms
  - User-friendly interface

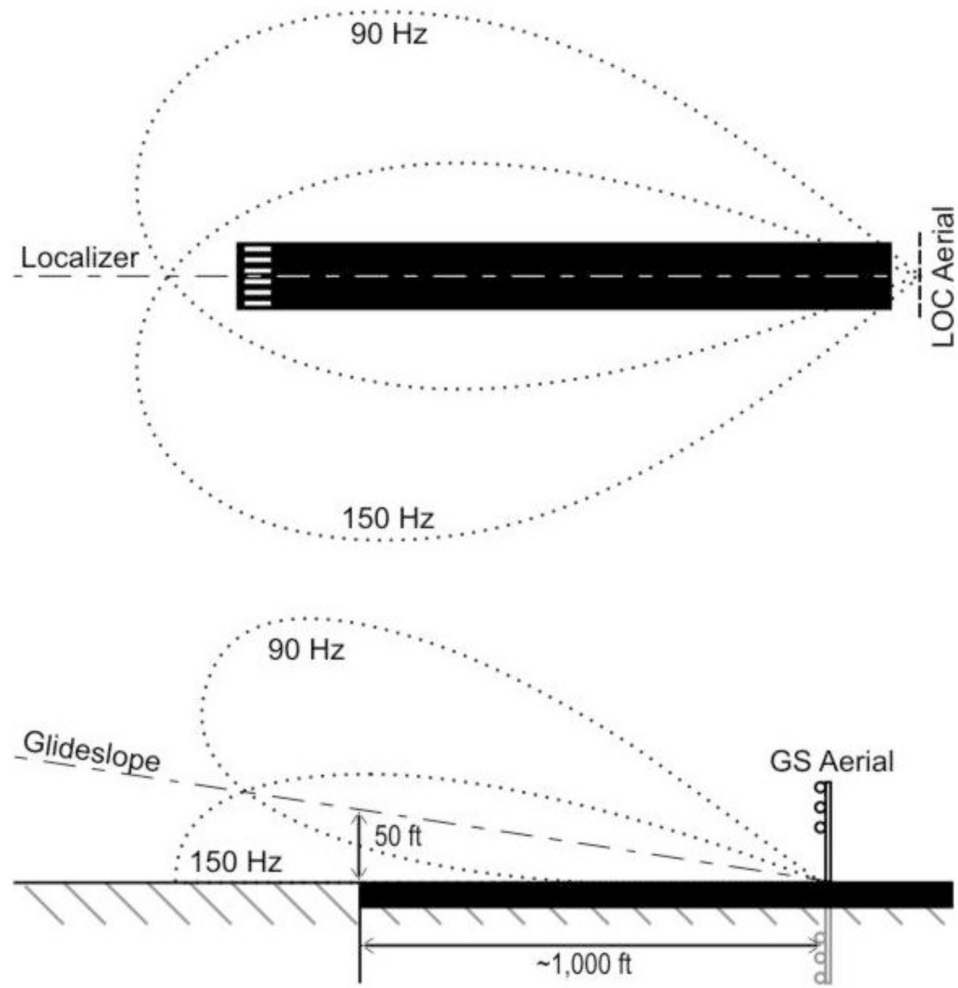
Questions?

Backup Slides

Instrument Landing System

- ILS consists of two radio transmitters each with a signal at 90 Hz and 150 Hz
  - VHF transmitter for Localizer
  - UHF transmitter for Glideslope

- Localizer and Glideslope receivers on aircraft measure Difference in Depth Modulation (DDM) of the 90Hz and 150 Hz signals.
  - DDM of localizer signal indicates if aircraft is left or right of centerline
  - DDM of glideslope signal indicates if aircraft is above or below glideslope
  - DDM of zero indicates aircraft is along centerline or glideslope



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